PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : G09G 3/02

A1

(11) International Publication Number: WO 95/09411

(43) International Publication Date: 6 April 1995 (06.04.95)

(21) International Application Number: PCT/US94/10590

(22) International Filing Date: 29 September 1994 (29.09.94)

(30) Pri rity Data:
128,112 29 September 1993 (29.09.93) US

(71) Applicant: VPL RESEARCH, INC. [US/US]; 3977 East Bayshore Road, Palo Alto, CA 94303 (US).

(72) Inventor: LANIER, Jaron, Z.; P.O. Box 2842, Sausalito, CA 94966 (US).

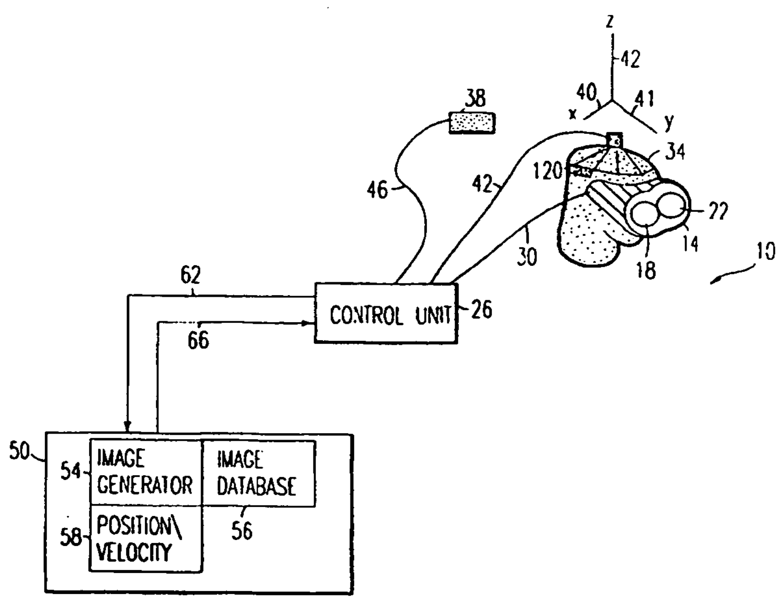
(74) Agents: GNUSE, Robert, F. et al.; Oblon, Spivak, McClelland, Maier & Neustadt, P.C., 4th floor, 1755 South Jefferson Davis Highway, Arlington, VA 22202 (US).

(81) Designated States: CA, JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: METHOD AND APPARATUS FOR DISPLAYING A VIRTUAL WORLD



(57) Abstract

A database (56) stores image data corresponding to an image which extends along first and second generally perpendicular image axes. A display device (14) is mounted for movement with the user's head in proximity to the user's eye, and an image generating circuit (54) generates a portion f the image n the display device (14) using coordinate data which varies only for the first and second imag axes. A movement measuring circuit (58) includes a plurality of radiation emitters disposed about the person's body part and a sensor (38) disposed at a fixed reference point which detects the identity of the radiation emitters and/or the intensity of radiation emitted by each emitter.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria
AU	Australia
BB	Barbados
BE	Belgium
BF	Burkina Faso
BG	Bulgaria
BJ	Benin
BR	Brazil
BY	Belarus
CA	Canada
CF	Central African Republic
CG	Congo
CH	Switzerland
CI	Côte d'Ivoire
CM	Cameroon
CN	China
CS	Czechoslovakia
CZ	Czech Republic
DE	Germany
DK	Denmark
ES	Spain
FI	Finland
FR	France
GA	Gabon
GB	United Kingdom
GE	Georgia
GN	Guinea
GR	Greece
HU	Hungary
IE	Ireland
IT	Italy
JP	Japan
KE	Kenya
KG	Kyrgystan
KP	Democratic People's Republic of Korea
KR	Republic of Korea
KZ	Kazakhstan
LI	Liechtenstein
LK	Sri Lanka
LU	Luxembourg
LV	Latvia
MC	Monaco
MD	Republic of Moldova
MG	Madagascar
ML	Mali
MN	Mongolia
MR	Mauritania
MW	Malawi
NE	Niger
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
RU	Russian Federation
SD	Sudan
SE	Sweden
SI	Slovenia
SK	Slovakia
SN	Senegal
TD	Chad
TG	Togo
TJ	Tajikistan
TT	Trinidad and Tobago
UA	Ukraine
US	United States of America
UZ	Uzbekistan
VN	Viet Nam

METHOD AND APPARATUS FOR DISPLAYING A VIRTUAL WORLD

BACKGROUND OF THE INVENTION

This invention relates to virtual reality systems and, more particularly, to an apparatus for displaying a virtual world.

Virtual reality systems use computers and peripheral devices to enable users to perceive and interact with computer generated worlds. In a typical virtual reality system, a user wears garments outfitted with devices which provide information about the position and orientation of the user relative to a fixed reference point. The information is used by the computer system to create a virtual being, wherein the virtual being emulates the position, orientation, and movements of the user. The database also includes a virtual environment in which the virtual being exists, and the virtual being may act upon virtual objects in the virtual world in a manner which emulates the actions of the user. For example, the virtual being may pick up a virtual ball and throw it, or the virtual being may use a virtual knife to cut a virtual steak.

To allow the user to perceive the virtual world and the actions his or her virtual being within it, the computer animates the virtual world together with the virtual being and projects the virtual world from the viewpoint of the virtual being onto a head-mounted display. As the user moves around, his or her actions are sensed by the instrumented garment and used by the computer to alter the position and orientation of the virtual being within the virtual world. The displayed image is also modified to follow the viewpoint of the virtual being so that the user is led to believe he or she actually exists in the virtual world. Thus, a user may lower his or her head and look underneath a virtual table, or the user may walk over to a

virtual light switch and, by appropriate movements of the user's hand, turn the switch on and off.

An important feature in any virtual reality system is the ability to animate and display the virtual world in a manner which makes the user believe he or she actually exists within the virtual world. For example, the displayed image must realistically translate and rotate as the user's head translates and rotates. Consequently, virtual worlds are usually rendered using a database which stores data for all three dimensions for every structure in the virtual world, and the structures are positioned, translated and rotated accordingly. Unfortunately, translation and rotation of structures in three-dimensional space, assignment of pixel values to correspond with the three dimensional view, and generation of the image on the head mounted display in real time requires substantial computing resources. This makes virtual reality systems very expensive and beyond the general consumer market.

SUMMARY OF THE INVENTION

The present invention is directed to a method and apparatus for displaying a virtual world which reduces the amount of computing resources needed to display the virtual world by rendering the virtual world using a reduced amount of image data. In one embodiment of the present invention, a database stores image data corresponding to an image which extends along first and second generally perpendicular image axes. A display device is mounted for movement with the user's head in proximity to the user's eye, and an image generating circuit generates a subportion of the image on the display device using coordinate data which varies only for the first and second image axes. A movement measuring circuit measures movement of a user's body part, such as the user's head, and, as the user moves (e.g., rotates his or her head), the image displayed is translated along one of the first or second image

axes by an amount proportional to the amount of movement. For example, if the user rotates his or her head about a vertical axis, the displayed image translates along the horizontal axis. The begin and end points of the image are logically coupled for forming a continuous 360° image. Thus, if the user rotates his or her head in a circle, he or she will view a continuous "cylindrical" world. The cylindrical world adequately simulates a three-dimensional virtual world, but without complicated and expensive three-dimensional graphics processing.

In the preferred embodiment, the display device comprises first and second display screens, one for each eye. The image displayed to one eye is offset by the image displayed to the other eye for providing a sense of depth. Multiple images may be superimposed on each other, each having a different offset, to further simulate a three dimensional environment.

The movement measuring circuit may comprise a plurality of radiation emitters disposed about the person's body part and a sensor disposed at a fixed reference point which detects the identity of the radiation emitters and/or the intensity of radiation emitted by each emitter. As the user rotates his or her body part, the sensor detects radiation from whichever radiation emitter is within view. The identity of the radiation emitters from which radiation is sensed may be used to calculate the rotational position and/or velocity of the user's body part. This data, in turn, may be used for translating the image on the display. Alternatively, a plurality of sensors may encircle the user's body part for sensing radiation emitted from a single radiation emitter. The identity of the sensors which receive radiation and/or the intensity of radiation received by the various sensors may be used to calculate the position and rotational velocity of the user's body part.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a diagram of portions of a virtual reality system including a particular embodiment of an apparatus according to the present invention for displaying a virtual world;

Figure 2 is a diagram of a particular embodiment of a two dimensional image displayed by the apparatus of Figure 1;

Figure 3 is a diagram showing how a portion of the image of Figure 2 is generated using graphical characters;

Figure 4 is a diagram showing how the virtual world is displayed to the user as a single cylinder;

Figure 5 is a diagram showing how the virtual world is displayed to each of the user's eyes;

Figure 6 is a diagram showing how the apparatus according to the present invention displays a virtual world comprising a plurality of superimposed cylinders;

Figures 7A, 7B, 8A, 8B, 8C, 9A and 9B are diagrams showing particular embodiments of movement measuring circuits according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 is a diagram of relevant portions of a virtual reality system 10 which incorporates features of the present invention. Virtual reality system 10 includes a head mounted display 14 for displaying images of a virtual world, position/tilt headgear 34 and a sensor 38 for providing data used for measuring the rotational position and velocity of the user's head about a horizontal X-axis 40 and a vertical Z-axis 42, a processor 50 for rendering the images in accordance with the data from headgear 34 and sensor 38, and a control unit 26 for interfacing head mounted display 14, headgear 34 and sensor 38 to processor 50. Head mounted display 14 is coupled to control unit 26 through a communication path 30, headgear 34 is coupled to control unit 26 through a communication path 42, sensor 38 is coupled to control unit 26 through a communication

path 46, and control unit 26 is coupled to processor 50 through communication paths 62 and 66.

Head mounted display 14 includes display screens 18 and 22 disposed in front of the user's eyes for displaying separate but overlapping images of the virtual world to each eye. Processor 50 includes an image generator 54, an image database 56, and a position/velocity calculating circuit 58. Position/velocity calculating circuit 58 receives the data from headgear 34 and sensor 38 through communication path 62 and calculates the rotational position and velocity of the user's head about axes 40 and 42. Image generator 54 uses the position and velocity calculations from position/velocity calculating circuit 58 in conjunction with the image data stored in image database 56 to render portions of the image which then may be communicated to control unit 26 through communication path 66 and thereafter to head mounted display 14 through communication path 30.

Figure 2 is a diagram showing a particular embodiment of an image 70 which may be stored in image data base 56. Image 70 extends along a horizontal X' axis 68 and a vertical Z' axis 70 as shown. In this embodiment, image 70 comprises a plurality of multi-pixel blocks of graphical characters 72(1,1) through 72(J,K), and the graphical characters extend from an address ADDR-1 to an address ADDR-K. Of course, the graphical characters need not be stored in contiguous physical locations within image data base 56 as long as the appropriate address pointers are capable of grouping the graphical characters together to form each displayed frame. Furthermore, there is not necessarily a one-to-one correspondence between the address number and the character number. The numbers used herein are for convenience in understanding only.

Image database also stores "sprites," such as sprite 80, which may be superimposed on image 70 in any desired location. Unlike image 70, sprites ordinarily comprise bit-mapped images rather than graphical characters, and they may be

superimposed on image 70 at any pixel location (ie., they need not be placed at character boundaries).

In this embodiment, M horizontal graphical characters and L vertical graphical characters comprise each displayed frame, where typically L<<K and M<<J. See Fig. 3. As the user rotates his or her head about X axis 40 and/or Z axis 42, the portions of the image displayed on display screens 18 and 22 change accordingly. Thus, as the user rotates his or her head about Z axis 42, image generator 54 may initially display the image located between addresses ADDR-1 and ADDR-M and then scroll to the image located between addresses ADDR-N and ADDR-(M+N). Preferably, the scrolling velocity is proportional to the rotational velocity of the user's head about the relevant axis.

Since the user may rotate his or her head more than 360°, it is necessary to accommodate this rotation by logically coupling the beginning address of the image (ADDR-1) to the end address of the image (ADDR-K) so that image generator renders a continuous "cylindrical" image as shown in Figs. 4-6. In this embodiment, the image at ADDR-1 through ADDR-M and ADDR-(J-M) through ADDR-J are duplicated. As the user rotates his or her head, e.g., clockwise about Z axis 42, the address pointer for image generator 54 increments until it reaches ADDR(J-M). At that time the address pointer value switches to ADDR(1), thus simulating the continuous image. The same thing occurs when the user rotates his or her head in the opposite direction.
Since the headgear 34 measures rotation of the user's head about horizontal X axis 40 as well, image generator 54 may display different vertical portions of image 70 depending on the rotational position of the user's head about axis 40 as shown in Figure 4.

In the preferred embodiment, the separate images displayed on display screens 18 and 22 are not exactly the same. Instead, they are offset in order to provide a stereo (depth) effect. For example, as shown in Fig. 5, the portion of the

image from ADDR(N) through ADDR(M+N) may be displayed to the user's left eye on display screen 22, while the portion of the image from ADDR(N+1) through ADDR(M+N+1) may be displayed to the user's right eye on display screen 18. Preferably, the images are offset by an integral number of graphical characters. The amount of separation may be set to control the perceived depth of the image. The further apart the images are, the closer the perceived image.

The foregoing may be extended to the maintenance of multiple images in one or more data bases for the generation of superimposed cylinder worlds. As shown in Fig. 6, multiple images may be superimposed where the offset for one image differs from the offset of another image. The image having the greater offset will appear closer. The composite image will appear three-dimensional, but without using a three-dimensional data base or three-dimensional graphics processing.

Figures 7A, 7B, 8A, 8B, 8C, 9A and 9B show various embodiments of those portions of headgear 34 used for measuring rotation about Z axis 42. Figure 7A shows an embodiment wherein a plurality, e.g., three radiation emitters 100(A-C) encircle the user's head, preferably in a common plane. Each radiation emitter may emit radiation at different frequencies, or else the individual radiation emitters may be selectively turned on and off so that the identity of the emitters may be ascertained using sensor 38 which is disposed generally perpendicular to the vertical axis of rotation. In the embodiment shown in Figure 7A, sensor 38 senses the intensity of radiation received from radiation emitters 100, 102 and 104 to determine which radiation emitter is in view of sensor 38 and which radiation emitter is closest to sensor 38. As shown in Figure 7B, the intensity of radiation received from radiation emitter 100 is less than the intensity of radiation received from emitter 102, and no radiation is sensed from emitter 104. This data may be used to calculate the rotational position of the user's head about Z axis 42.

Figures 8A, 8B and 8C show another embodiment of headgear 34 wherein numerous radiation emitters 102A-L encircle the user's head. This device may operate the same way as the device shown in Figure 7A wherein the identity of and intensity from the various radiation emitters are used to calculate the rotational position of the user's head. Alternatively, since many radiation emitters are disposed about the user's head, the rotational position of the user's head may be accurately ascertained merely by identifying which radiation emitter is in view.

Figures 9A, 9B, and 9C show another embodiment of a rotation measuring device similar to the device shown in Figure 8A, except a plurality of radiation sensors encircle the user's head for sensing radiation from a single radiation emitter 112. As shown in Figure 9B, the intensity of radiation received by each sensor together with its identity may be used to ascertain the rotational position of the user's head. Alternatively, as in the embodiment shown in Figure 8A, the rotational position of the user's head may be ascertained by the identity of sensors which receive any radiation at all from emitter 38A as shown in Figure 9C.

In all embodiments the rotational velocity of the user's head may be measured by the rate of change in amplitude of the sensed radiation or by the rate of change of the identified sensors. Alternatively, force-sensitive resistors may be used to measure torque and hence acceleration and velocity. Backup sensors (e.g., in the form of additional radiation emmiters and sensors) may be employed to prevent false indications of motion or no motion under constant acceleration conditions.

The same schemes may be used to calculate the rotational position and velocity of the user's head about X axis 40. However, in this embodiment a pitch sensor 120 is used to measure the degree of pitch of the user's head. Pitch sensor 120 may comprise a conventional bead sensor which employs

gravity to measure the degree of pitch, or some other well-known pitch sensor.

While the above is a complete description of a preferred embodiment of the present invention, various modifications may be employed. For example, any body part of the user may be used to control scrolling of the image (such as the user's hand). Consequentially, the scope of the invention should be ascertained by the following claims.

WHAT IS CLAIMED IS:

1. An apparatus for displaying a virtual world comprising:

image storing means for storing image data representing an image which extends along first and second generally perpendicular image axes;

movement measuring means for measuring movement of a body part of the user;

a display screen mounted for movement with the user's head in front of the user's eyes; and

image generating means, electrically coupled to the image storing means, to the movement measuring means, and to the display means, for generating a portion of the image on the display screen using coordinate data which varies only for the first and second image axes, the image generating means including image translating means for generating a portion of the image on the display screen that is translated along one of the first or second image axes by an amount proportional to an amount of movement of the user's body part.

2. The apparatus according to claim 1 wherein the image storing means stores only a two-dimensional image comprising multi-pixel blocks of graphical characters.

3. The apparatus according to claim 1 wherein the movement measuring means comprises rotation measuring means for measuring rotation of the user's body part, and wherein the image translating means generates a portion of the image that is translated by an amount proportional to the amount of rotation of the user's body part.

4. The apparatus according to claim 3 wherein the first axis is a horizontal axis and the second axis is a vertical axis, and wherein the image translating means generates

a portion of the image that is translated along the horizontal axis by an amount proportional to the amount of rotation of the user's body part.

5. The apparatus according to claim 3 wherein the rotation measuring means comprises vertical head rotation measuring means for measuring the amount of rotation of the user's head about the vertical axis, so that the image translating means translates the portion of the image along the horizontal axis by an amount proportional to the amount of rotation of the user's head about the vertical axis.

6. The apparatus according to claim 5 wherein the rotation means further comprises horizontal head rotation measuring means for measuring the amount of rotation of the user's head about the horizontal axis, and wherein the image translating means generates a portion of the image that is translated along the vertical axis by an amount proportional to the amount of rotation of the user's head about the horizontal axis.

7. The apparatus according to claim 3 wherein the image has a start point and an end point along the first axis, and wherein the image generating means couples the start point to the end point when generating the image so that a continuous 360 degree image is displayed to the user as the user's body part rotates about the second axis.

8. The apparatus according to claim 7 wherein the first axis is a horizontal axis and the second axis is a vertical axis, and wherein the image translating means generates a portion of the image that is translated along the horizontal axis by an amount proportional to the amount of rotation of the user's body part about the vertical axis.

9. The apparatus according to claim 8 wherein the rotation measuring means comprises vertical head rotation measuring means for measuring the amount of rotation of the user's head about the vertical axis, so that the portion of the image is translated along the horizontal axis by an amount proportional to the amount of rotation of the user's head about the vertical axis.

10. The apparatus according to claim 9 wherein the rotation means further comprises horizontal head rotation measuring means for measuring the amount of rotation of the user's head about the horizontal axis, and wherein the image translating means generates a portion of the image that is translated along the vertical axis by an amount proportional to the amount of rotation of the user's head about the horizontal axis.

11. The apparatus according to claim 10 wherein the image storing means stores only a two-dimensional representation of the image comprising multi-pixel blocks of graphical characters.

12 A method for displaying a virtual world comprising:

storing image data representing an image which extends along first and second generally perpendicular image axes;

measuring movement of a body part of the user;

mounting a display screen for movement with the user's head in front of the user's eyes; and

generating a portion of the image on the display screen using coordinate data which varies only for the first and second image axes, the portion of the image being translated along one of the first or second image axes by an amount proportional to an amount of movement of the user's body part.

13. The method according to claim 12 wherein the image data storing step comprises the step of storing only a two-dimensional image comprising multi-pixel blocks of graphical characters.

14. The method according to claim 12 wherein the movement measuring step comprises the step of measuring rotation of the user's body part, and wherein the image generating step comprises the step of generating a portion of the image that is translated by an amount proportional to the amount of rotation of the user's body part.

15. The method according to claim 14 wherein the first axis is a horizontal axis and the second axis is a vertical axis, and wherein the image generating step further comprises the step of generating a portion of the image that is translated along the horizontal axis by an amount proportional to the amount of rotation of the user's body part.

16. The method according to claim 15 wherein the rotation measuring step further comprises the step of measuring the amount of rotation of the user's head about the vertical axis, and wherein the image generating step further comprises the step of generating a portion of the image that is translated along the horizontal axis by an amount proportional to the amount of rotation of the user's head.

17. The method according to claim 16 wherein the rotation measuring step further comprises the step of measuring the amount of rotation of the user's head about the horizontal axis, and wherein the image generating step comprises the step of generating a portion of the image that is translated along the vertical axis by an amount proportional to the amount of rotation of the user's head about the horizontal axis.

18. The method according to claim 14 wherein the image has a start point and an end point along the first axis, and wherein the image generating step further comprises the step of coupling the start point to the end point when generating the image so that a continuous 360 degree image is displayed to the user as the user's body part rotates about the second axis.

19. The method according to claim 18 wherein the first axis is a horizontal axis and the second axis is a vertical axis, and wherein the image generating step further comprises the step of generating a portion of the image that is translated along the horizontal axis by an amount proportional to the amount of rotation of the user's body part.

20. The method according to claim 19 wherein the rotation measuring step comprises the step of measuring the amount of rotation of the user's head about the vertical axis, and wherein the image generating step further comprises the step of generating a portion of the image that is translated along the horizontal axis by an amount proportional to the amount of rotation of the user's head about the vertical axis.

21. The method according to claim 20 wherein the rotation measuring step further comprises the step of measuring the amount of rotation of the user's head about the horizontal axis, and wherein the image generating step further comprises the step of generating a portion of the image that is translated along the vertical axis by an amount proportional to the amount of rotation of the user's head about the horizontal axis.

22. The method according to claim 21 wherein the image storing step comprises the step of storing only a two-dimensional representation of the image comprising multi-pixel blocks of graphical characters.

23. An apparatus for displaying a virtual world comprising:

image storing means for storing image data representing a first image which extends along first and second generally perpendicular image axes;

movement measuring means for measuring movement of a body part of the user;

first and second display screens mounted for movement with the user's head, the first display screen being disposed in front of a first one of the user's eyes, and the second display screen being disposed in front of a second one of the user's eyes; and

image generating means, electrically coupled to the image storing means, to the movement measuring means, to the first display screen, and to the second display screen, for generating a portion of the first image on the first and second display screens using coordinate data which varies only for the first and second image axes, the image generating means including image translating means for generating a portion of the first image on the first and second display screens that is translated along one of the first or second image axes by an amount proportional to an amount of movement of the user's body part.

24. The apparatus according to claim 23 wherein the portion of the first image generated on the first display screen is offset from the portion of the first image generated on the second display screen.

25. The apparatus according to claim 24 wherein the image storing means stores only a two-dimensional images comprising multi-pixel blocks of graphical characters, and wherein the portion of the first image generated on the first display screen is offset along the first axis from the portion

of the first image generated on the second display screen by a first selected number of graphical characters.

26. The apparatus according to claim 25 wherein the image storing means additionally stores image data representing a second image which extends along the first and second image axes, wherein the image generating means generates a portion of the second image on the first and second display screens using coordinate data which varies only for the first and second image axes, the second image being superimposed on the first image, wherein the image translating means generates a portion of the second image on the first and second display screens that is translated along one of the first or second image axes by an amount proportional to an amount of movement of the user's body part, and wherein the portion of the second image generated on the first display screen is offset from the portion of the second image generated on the second display screen by a second selected number of graphical characters, the second number being different from the first number.

27. The apparatus according to claim 26 wherein the movement measuring means comprises rotation measuring means for measuring rotation of the user's body part, and wherein the image translating means generates portions of the first and second image that are translated by an amount proportional to the amount of rotation of the user's body part.

28. The apparatus according to claim 27 wherein the first axis is a horizontal axis and the second axis is a vertical axis, and wherein the image translating means generates portions of the first and second images that are translated along the horizontal axis by an amount proportional to the amount of rotation of the user's body part.

29. The apparatus according to claim 28 wherein the rotation measuring means comprises vertical head rotation measuring means for measuring the amount of rotation of the user's head about the vertical axis, so that the image translating means generates portions of the first and second images that are translated along the horizontal axis by an amount proportional to the amount of rotation of the user's head about the vertical axis.

30. The apparatus according to claim 29 wherein the rotation means further comprises horizontal head rotation measuring means for measuring the amount of rotation of the user's head about the horizontal axis, and wherein the image translating means generates portions of the first and second images that are translated along the vertical axis by an amount proportional to the amount of rotation of the user's head about the horizontal axis.

31. The apparatus according to claim 27 wherein the first and second images each have a start point and an end point along the first axis, and wherein the image generating means couples the start point in the first and second images to the respective end points when generating the first and second images so that continuous 360 degree first and second images are displayed to the user as the user's body part rotates about the second axis.

32. The apparatus according to claim 31 wherein the first axis is a horizontal axis and the second axis is a vertical axis, and wherein the image translating means generates portions of the first and second images that are translated along the horizontal axis by an amount proportional to the amount of rotation of the user's body part.

33. The apparatus according to claim 32 wherein the rotation measuring means comprises vertical head rotation measuring means for measuring the amount of rotation of the user's head about the vertical axis, so that the image translating means generates portions of the first and second images that are translated along the horizontal axis by an amount proportional to the amount of rotation of the user's head about the vertical axis.

34. The apparatus according to claim 33 wherein the rotation means further comprises horizontal head rotation measuring means for measuring the amount of rotation of the user's head about the horizontal axis, and wherein the image translating means generates portions of the images that are translated along the vertical axis by an amount proportional to the amount of rotation of the user's head about the horizontal axis.

35. The apparatus according to claim 34 wherein the image storing means stores a bit map of a third image, wherein the image generating means generates the third image on the first and second display screens and superimposes the third image on at least one of the first and second images, and wherein the portion of the third image generated on the first display screen is offset along the first axis from the portion of the third image generated on the second display screen by a selected number of pixels.

36. A method for displaying a virtual world comprising the steps of:

storing image data representing a first image which extends along first and second generally perpendicular image axes;

measuring movement of a body part of the user;

mounting first and second display screens for movement with the user's head, the first display screen being disposed in front of a first one of the user's eyes, and the second display screen being disposed in front of a second one of the user's eyes; and

generating a portion of the first image on the first and second display screens using coordinate data which varies only for the first and second image axes, the portion of the first image on the first and second display screens being translated along one of the first or second image axes by an amount proportional to an amount of movement of the user's body part.

37. The method according to claim 36 wherein the portion of the first image generated on the first display screen is offset from the portion of the first image generated on the second display screen.

38. The method according to claim 37 wherein the image storing step comprises the step of stores only a two-dimensional images comprising multi-pixel blocks of graphical characters, and wherein the portion of the first image generated on the first display screen is offset from the portion of the first image generated on the second display screen by a first selected number of graphical characters.

39. The apparatus according to claim 38 wherein the image storing step further comprises the step of additionally storing image data representing a second image which extends along the first and second image axes, wherein the image generating step further comprises the step of generating a portion of the second image on the first and second display screens using coordinate data which varies only for the first and second image axes, the second image being superimposed on the first image, the portion of the second image on the first

and second display screens being translated along one of the first or second image axes by an amount proportional to an amount of movement of the user's body part, and wherein the portion of the second image generated on the first display screen is offset from the portion of the second image generated on the second display screen by a second selected number of graphical characters, the second number being different from the first number.

40. The method according to claim 39 wherein the movement measuring step comprises the step of measuring rotation of the user's body part, and wherein the image generating step further comprises the step of generating portions of the first and second image that are translated by an amount proportional to the amount of rotation of the user's body part.

41. The method according to claim 40 wherein the first axis is a horizontal axis and the second axis is a vertical axis, and wherein the image generating step further comprises the step of generating portions of the first and second images that are translated along the horizontal axis by an amount proportional to the amount of rotation of the user's body part.

42. The method according to claim 41 wherein the rotation measuring step comprises further comprises the step of measuring the amount of rotation of the user's head about the vertical axis, and wherein the image geerating step further comprises the step of generating portions of the first and second images that are translated along the horizontal axis by an amount proportional to the amount of rotation of the user's head about the vertical axis.

43. The method according to claim 42 wherein the rotation measuring step further comprises the step of measuring

the amount of rotation of the user's head about the horizontal axis, and wherein the image generating step further comprises the step of generating portions of the first and second images that are translated along the vertical axis by an amount proportional to the amount of rotation of the user's head about the horizontal axis.

44. The method according to claim 40 wherein the first and second images each have a start point and an end point along the first axis, and wherein the image generating step further comprises the step of coupling the start point in the first and second images to the respective end points so that continuous 360 degree first and second images are displayed to the user as the user's body part rotates about the second axis.

45. The method according to claim 44 wherein the first axis is a horizontal axis and the second axis is a vertical axis, and wherein the image generating step further comprises the step of generating portions of the first and second images that are translated along the horizontal axis by an amount proportional to the amount of rotation of the user's body part.

46. The method according to claim 45 wherein the rotation measuring step further comprises the step of measuring the amount of rotation of the user's head about the vertical axis, and wherein the image generating step further comprises the step of generating portions of the first and second images that are translated along the horizontal axis by an amount proportional to the amount of rotation of the user's head about the vertical axis.

47. The method according to claim 46 wherein the rotation measuring step further comprises the step of measuring the amount of rotation of the user's head about the horizontal

axis, and wherein the image generating step further comprises the step of generating portions of the images that are translated along the vertical axis by an amount proportional to the amount of rotation of the user's head about the horizontal axis.

48. The method according to claim 47 wherein the image storing step further comprises the step of storing a bit map of a third image, wherein the image generating step further comprises the step of generating the third image on the first and second display screens and superimposing the third image on at least one of the first and second images, and wherein the portion of the third image generated on the first display screen is offset along the first axis from the portion of the third image generated on the second display screen by a selected number of pixels.

49. An apparatus for measuring positional characteristics of a body comprising:

a plurality of radiation emitters encircling the body;

a radiation sensor positioned for sensing radiation from different ones of the plurality of emitters depending upon a radial position of the body about an axis; and

positional characteristic measuring means for measuring positional characteristics of the body about the axis, the positional characteristic measuring means comprising:

first emitter identifying means, electrically coupled to the sensor, for identifying the emitters for which radiation is being sensed by the sensor at a first time; and

first position calculating means, electrically coupled to the emitter identifying means, for calculating a first radial position of the body about the axis based on the identified emitters.

50. The apparatus according to claim 49 wherein the positional characteristic measuring means further comprises:

first amplitude measuring means, electrically coupled to the sensor, for measuring the amplitude of radiation sensed for each identified emitter at the first time; and

wherein the first position calculating means is electrically coupled to the first amplitude measuring means for calculating the first radial position of the body about the axis based on the amplitude of radiation sensed for each identified emitter at the first time.

51. The apparatus according to claim 49 wherein the positional characteristic measuring means further comprises:

second emitter identifying means for identifying the emitters for which radiation is being sensed by the sensor at a second time; and

velocity calculating means, electrically coupled to the first emitter identifying means and to the second emitter identifying means, for calculating rotational velocity of the body about the axis based on the emitters identified at the first and second times.

52. The apparatus according to claim 51 wherein the positional characteristic measuring means further comprises: second amplitude measuring means, electrically coupled to the sensor, for measuring the amplitude of radiation sensed for each identified emitter at the second time; and

wherein the velocity calculating means is electrically coupled to the second amplitude measuring means for calculating the rotational velocity of the body about the axis based on the amplitude of radiation sensed for each identified emitter at the first and second times.

53. The apparatus according to claim 52 wherein the sensor is disposed generally perpendicularly to the axis.

54. The apparatus according to claim 53 wherein the plurality of emitters generally lie within a common plane.

55. The apparatus according to claim 54 wherein the plurality of emitters are disposed on a headpiece adapted to be worn by a person.

56. The apparatus according to claim 55 wherein each radiation emitter emits radiation having a different frequency.

57. A method for measuring positional characteristics of a body comprising the steps of:

encircling the body with a plurality of radiation emitters;

positioning a radiation sensor for sensing radiation from different ones of the plurality of emitters depending upon a radial position of the body about an axis;

identifying the emitters for which radiation is being sensed by the sensor at a first time; and

calculating a first radial position of the body about the axis based on the identified emitters.

58. The method according to claim 57 further comprising the step of measuring the amplitude of radiation sensed for each identified emitter at the first time, and wherein the first position calculating step comprises the step of calculating the first radial position of the body about the axis based on the amplitude of radiation sensed for each identified emitter at the first time.

59. The method according to claim 57 further comprising the steps of:

identifying the emitters for which radiation is being sensed by the sensor at a second time; and

calculating rotational velocity of the body about the axis based on the emitters identified at the first and second times.

60. The method according to claim 59 further comprising the step of measuring the amplitude of radiation sensed for each identified emitter at the second time, and wherein the velocity calculating step further comprises the step of calculating the rotational velocity of the body about the axis based on the amplitude of radiation sensed for each identified emitter at the first and second times.

61. The method according to claim 60 wherein the sensor is positioned generally perpendicularly to the axis.

62. The method according to claim 61 wherein the plurality of emitters generally lie within a common plane.

63. The method according to claim 62 wherein the plurality of emitters are disposed about the head of a person.

64. The method according to claim 63 wherein each radiation emitter emits radiation having a different frequency.

65. An apparatus for measuring positional characteristics of a body comprising:

a radiation emitter;

a plurality of radiation sensors encircling the body, the sensors being positioned so that selected ones of the plurality of radiation sensors sense radiation from the emitter depending upon a radial position of the body about an axis;

positional characteristic measuring means for measuring positional characteristics of the body about the axis, the positional characteristic measuring means comprising:

first sensor identifying means, electrically coupled to the plurality of sensors, for identifying the sensors which sense radiation from the emitter at a first time; and

first position calculating means, electrically coupled to the first sensor identifying means, for calculating a first radial position of the body about the axis based on the identified sensors.

66. The apparatus according to claim 65 wherein the positional characteristic measuring means further comprises: first amplitude measuring means, electrically coupled to the plurality of sensors, for measuring the amplitude of radiation sensed by each identified sensor at the first time; and

wherein the first position calculating means is electrically coupled to the first amplitude measuring means for calculating the first radial position of the body about the axis based on the amplitude of radiation sensed for each identified sensor at the first time.

67. The apparatus according to claim 65 wherein the positional characteristic measuring means further comprises:

second sensor identifying means for identifying the sensors which sense radiation from the emitter at a second time; and

velocity calculating means, electrically coupled to the first sensor identifying means and to the second sensor identifying means, for calculating rotational velocity of the body about the axis based on the sensors identified at the first and second times.

68. The apparatus according to claim 67 wherein the positional characteristic measuring means further comprises: second amplitude measuring means, electrically coupled to the

plurality of sensors, for measuring the amplitude of radiation sensed by each identified sensor at the second time; and

wherein the velocity calculating means is electrically coupled to the second amplitude measuring means for calculating the rotational velocity of the body about the axis based on the amplitude of radiation sensed by each identified sensor at the first and second times.

69. The apparatus according to claim 68 wherein the emitter is disposed generally perpendicularly to the axis.

70. The apparatus according to claim 69 wherein the plurality of sensors generally lie within a common plane.

71. The apparatus according to claim 70 wherein the plurality of emitters are disposed on a headpiece adapted to be worn by a person.

72. A method for measuring positional characteristics of a body comprising the steps of:

positioning a radiation emitter for emitting radiation toward the body;

encircling the body with a plurality of radiation sensors so that selected ones of the plurality of radiation sensors sense radiation from the emitter depending upon a radial position of the body about an axis;

identifying the sensors which sense radiation from the emitter at a first time; and

calculating a first radial position of the body about the axis based on the identified sensors.

73. The method according to claim 72 further comprising the step of measuring the amplitude of radiation sensed by each identified sensor at the first time, and wherein the first position calculating step comprises the step of

calculating the first radial position of the body about the axis based on the amplitude of radiation sensed by each identified sensor at the first time.

74. The method according to claim 72 further comprising the steps of:

identifying the sensors which sense radiation from the emitter at a second time; and

calculating rotational velocity of the body about the axis based on the sensors identified at the first and second times.

75. The method according to claim 74 further comprising the step of measuring the amplitude of radiation sensed by each identified sensor at the second time, and wherein the velocity calculating step further comprises the step of calculating the rotational velocity of the body about the axis based on the amplitude of radiation sensed by each identified sensor at the first and second times.

76. The method according to claim 75 wherein the emitter is positioned generally perpendicularly to the axis.

77. The method according to claim 76 wherein the plurality of sensors generally lie within a common plane.

78. The method according to claim 77 wherein the plurality of sensors are disposed about the head of a person.

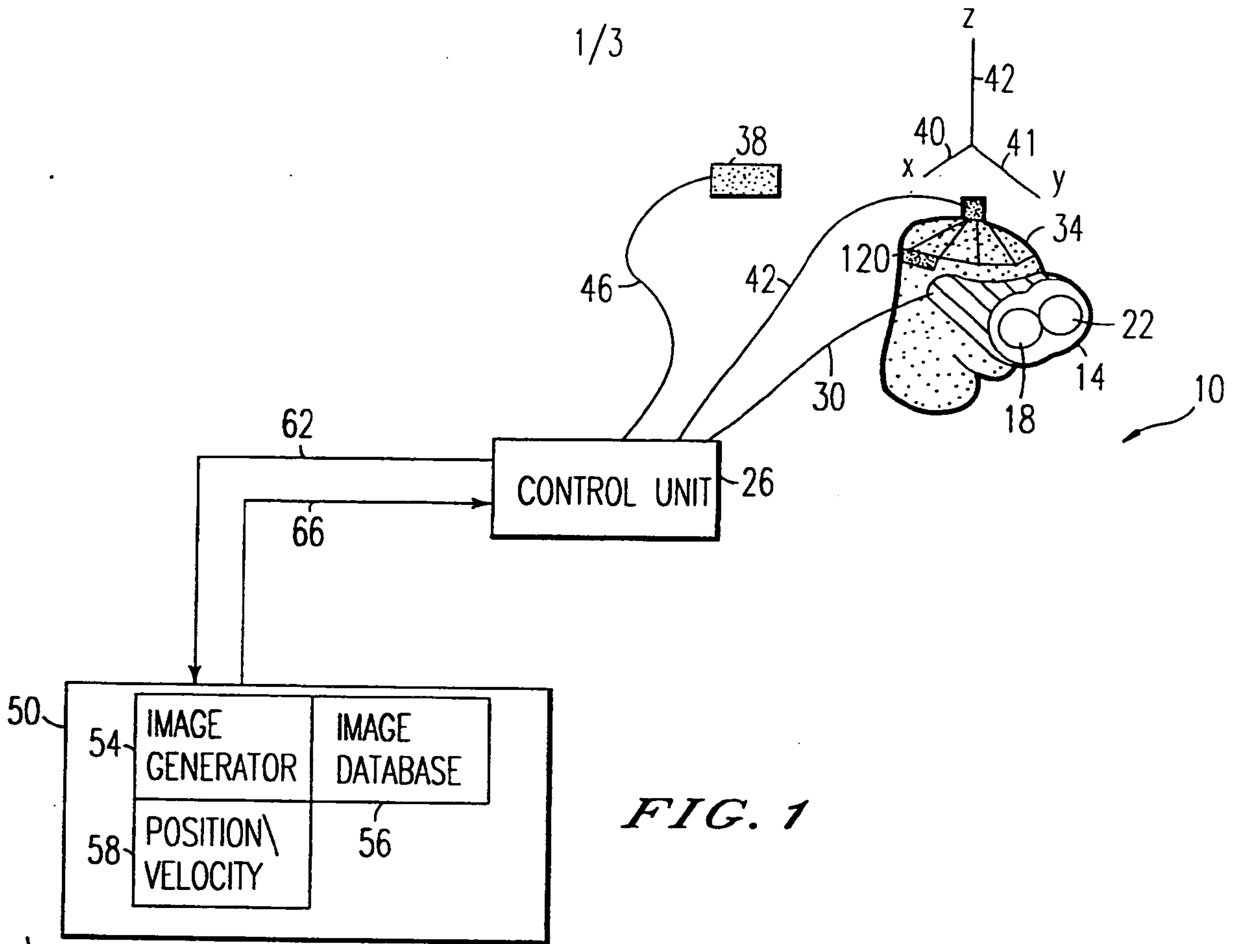


FIG. 1

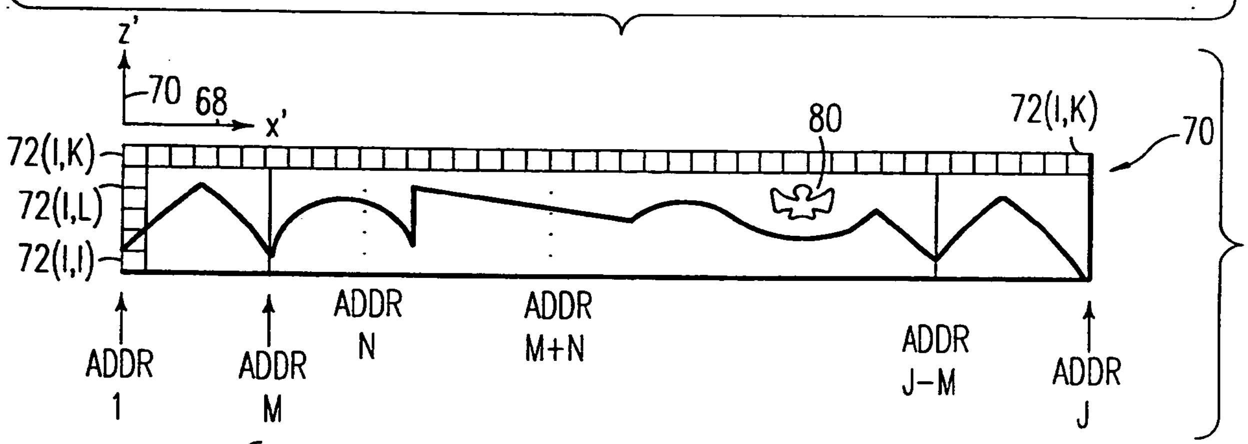


FIG. 2

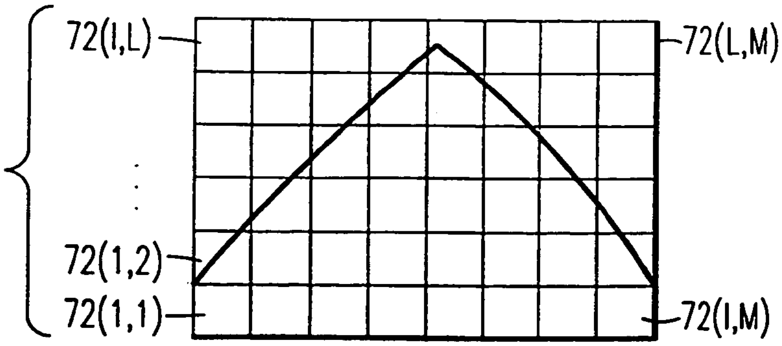


FIG. 3

SUBSTITUTE SHEET (RULE 26)

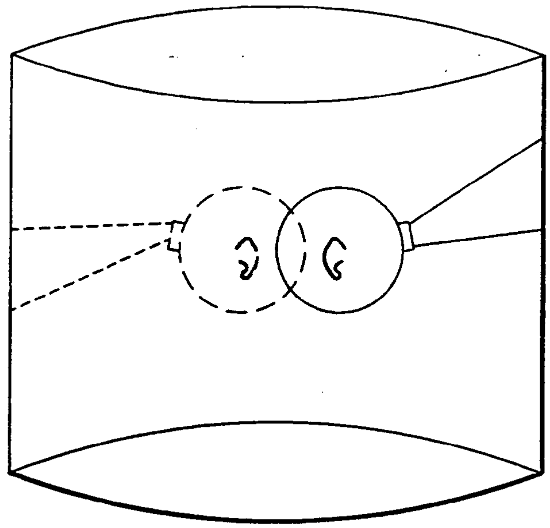


FIG. 4

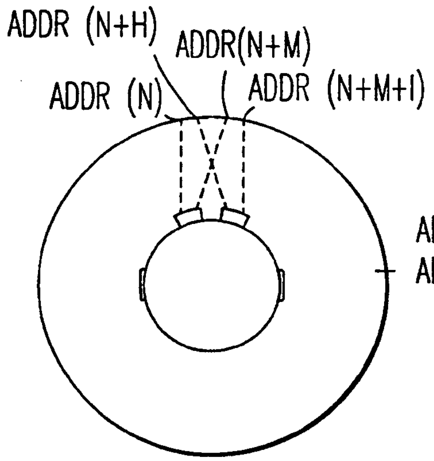


FIG. 5

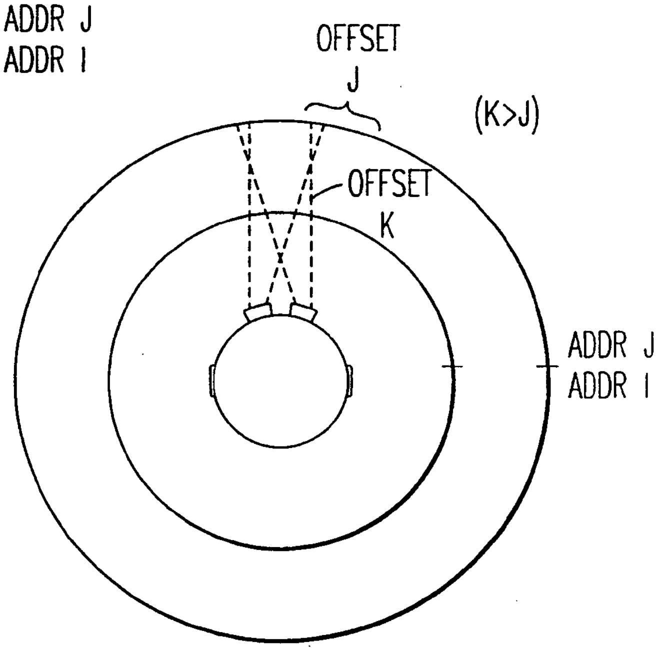


FIG. 6

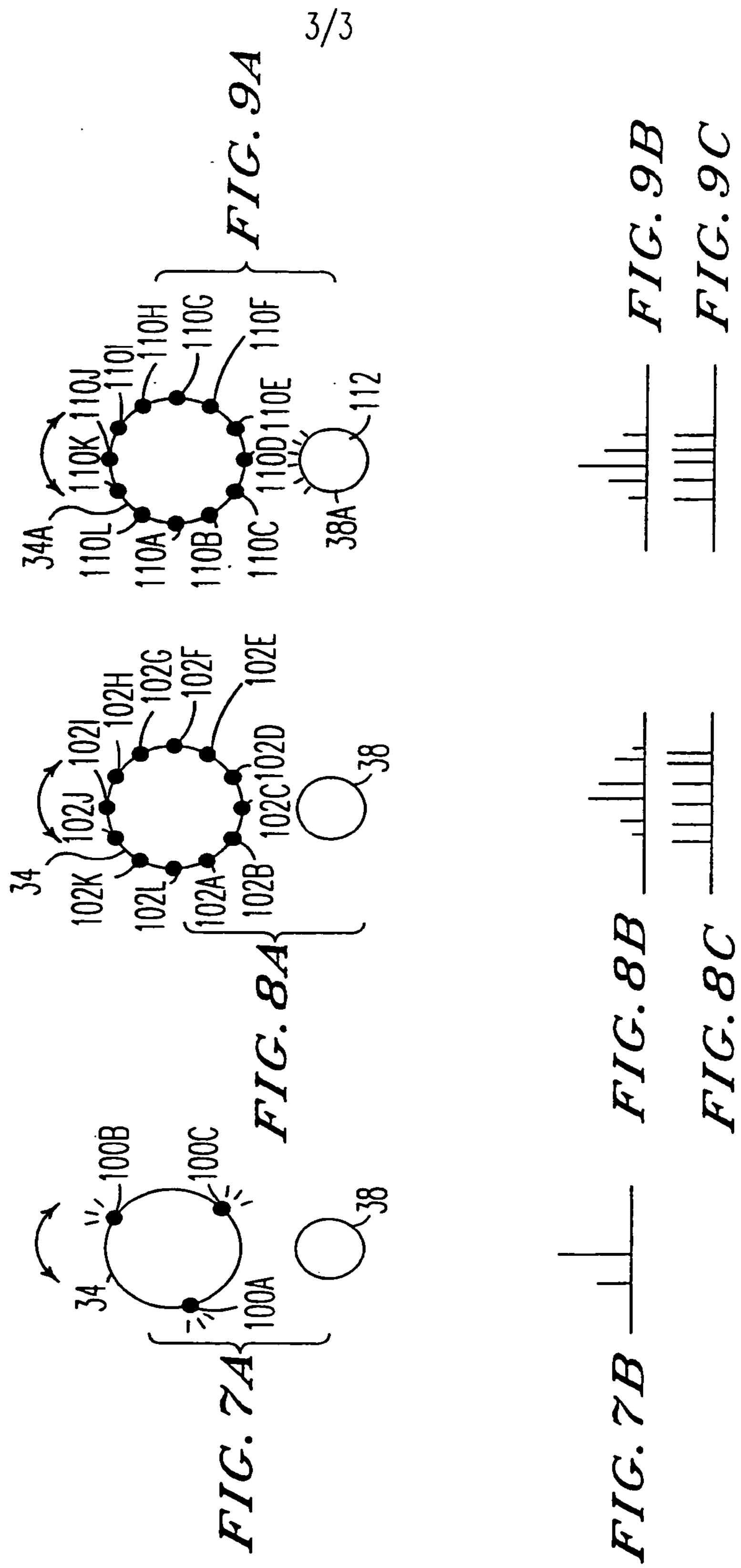


FIG. 7A

FIG. 8A

FIG. 9A

FIG. 7B

FIG. 8B

FIG. 8C

FIG. 9B

FIG. 9C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/10590

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :G09G 3/02
US CL :345/7, 8
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 345/7, 8, 9, 156; 348/77, 121, 142, 699; 434/22, 43, 44, 46, 55, 57; 353/13, 14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,177,872 (LEWIS ET AL) 12 January 1993, col.3, lines 29-53.	1-48
Y	US, A, 4, 807,202 (CHERRI ET AL) 21 February 1989, col 4, lines 45-62 and col 5, lines 26-53.	49-78
Y	US, A, 4,984,179 (WALDERN) 08 January 1991, col. 6, lines 64-68 and col. 5, lines 1-64	1-78

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be part of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier document published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search 17 FEBRUARY 1995	Date of mailing of the international search report 10 MAR 1995
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer CHANH NGUYEN Teleph n N . (703) 308-6603